Lower Passaic River Feasibility Study
Proposal for the Subsurface Remedial Action Level
to Achieve Remedial Action Objective 2

The goal of Remedial Action Objective (RAO) 2 is to control subsurface sediments (sediments greater than 6 inches below the sediment bed) from becoming sources of 2,3,7,8-TCDD and total PCBs by remediating sediments between river mile (RM) 8.3 and RM 15 that have a demonstrated potential for erosion to expose subsurface concentrations above defined subsurface remedial action levels (RALs) established for 2,3,7,8-TCDD and total PCBs.

This potential is defined by the magnitude of the subsurface concentrations, the area over which they exist and the likelihood of exposure. In simple terms, this potential can be described as follows:

$$Potential = \mathcal{L}cA$$

where:

$\mathcal{L}$	=	likelihood of exposure
c	=	concentration
A	=	area

The product of $\mathcal{L}$ and c can be thought of as the effective subsurface concentration. A low concentration with a high likelihood of exposure may be as effective in its potential to be a source as a much higher concentration with a low likelihood of exposure.

The area (A) can be identified by bed elevation changes between multibeam bathymetric surveys conducted in 2007, 2008, 2010, 2011, and 2012 (e.g., using the "Erosional" and "Erosion and Deposition" portions of the river bottom identified in Section 4 of the Remedial Investigation [RI] Report). For areas not covered by the bathymetric surveys (as documented in the RI Report), the predictions of the Cooperating Parties Group (CPG) Lower Passaic River (LPR) sediment transport model can be used.

Although the upper 9 miles of the LPR are thought to be in a dynamic equilibrium on the large scale, erosion does occur on local scales as evidenced by the 2007 to 2012 multibeam survey series. Erosion of sediments is controlled by the shear stress at the river bottom and the resistance of the sediments to this stress. The shear stress is driven by the velocity of the overlying water and the roughness of the sediment surface. The velocities vary with the tides and with the upstream river flow.[1] They are greatest during extreme high-flow events. The spatial patterns of high-flow-event velocities are driven by river

[1]They are also influenced by waves and boats but to a much less extent, except in localized areas

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geometry, sinuosity, and bottom roughness. Though there is some randomness to this pattern, it is largely predictable with some areas sheltered from high stresses and others exposed to these stresses during each event. Erosion patterns in the multibeam bathymetry surveys indicate that areas experiencing the highest stresses typically include the channel bottom and side-slopes, particularly outside channel side-slopes on bends or in regions of flow constriction (e.g., near bridge abutments). Areas of cyclical erosion and deposition, such as those observed along the inner bend of the RM 10.9 shoal, likely reflect the accumulation of mobile sediments on top of a bed that has been armored by past high-flow events, making it more resistant to further erosion.

Buried 2,3,7,8-TCDD concentrations (which will be mapped by future high-density pre-design sediment sampling) are generally expected to have a low likelihood ($\mathcal{L}$) of exposure. This is so because they are still in the subsurface despite being subjected to a number of extreme high-flow events, including a 90-year flow that resulted from Hurricane Irene in 2011. The exception to this are locations where the buried concentrations are associated with recently deposited sediments that may be more vulnerable to erosion than older sediments. In this case, the buried concentrations likely reflect recent water column particulate concentrations depositing onto the sediment bed and not the much higher concentrations associated with older sediments.

The likelihood ($\mathcal{L}$) that sediments that experienced erosion of 6 inches or more would experience an additional 6 inches or more of erosion was investigated using the bed elevation changes between multi-beam bathymetry surveys (the threshold of 6 inches was identified in the RI Report based on the accuracy of the multibeam surveys). Sediments that experienced erosion between surveys in 2008 and 2010 were chosen as the test locations. Erosion potential was likely high during this period because of a 25-year flow event (about 16,000 cubic feet per second [cfs]) that occurred about 1 month before the 2010 bathymetric survey.

These locations were tracked for subsequent elevation change in response to two extreme-flow events (greater than 10,000 cfs) that occurred prior to the bathymetric survey in October 2011, including the 90-year flow associated with Hurricane Irene in September 2011. They are not the only locations where erosion might occur in the later events, but they are tests for the proposition that the armoring and deepening caused by prior erosion reduces the likelihood of further erosion.

Between RM 8.3 and RM 15, 26.4 acres experienced erosion between 2008 and 2010 (6 inches or more). Of these, only 6.3 acres experienced further erosion between 2010 and 2012 of 6 inches or more, with the remainder experiencing no measurable change or net deposition[2] (Table 1). A map of these locations is provided in Figure 1.

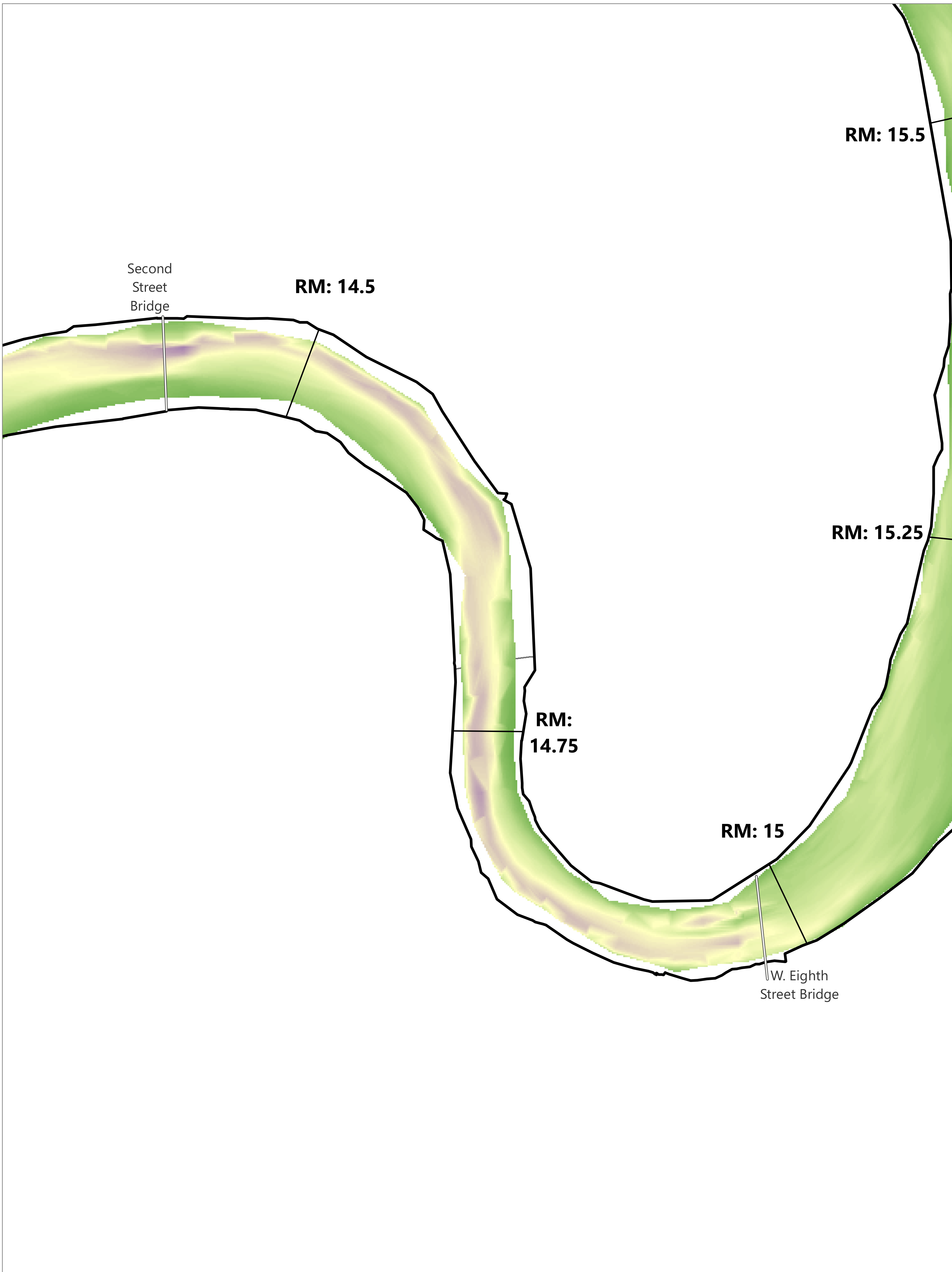
[2] The categories presented in Table 1 are based on the maximum erosion observed when comparing the 2010 survey to both the 2011 and 2012 surveys.

These findings suggest that $\mathcal{L}$ may be expected to be about 0.25. This yields an effective subsurface concentration ($\mathcal{L} * c$ as defined above) that is one fourth the measured concentration. Thus, a subsurface RAL four times the surface sediment RAL should be considered equivalent to the surface sediment RAL from the perspective of controlling erosional impacts to the surface sediment surface-weighted average concentration (SWAC).

To be conservative, a value of 0.5 was chosen for assessing the potential for erosion to provide a source of subsurface concentrations of 2,3,7,8-TCDD and total PCBs. Therefore, the CPG proposes to use a subsurface RAL that is two times the surface RAL for developing the RAO 2 subsurface footprints for the remedial alternatives in the Interim Remedy Feasibility Study for the upper 9 miles.

Table 1
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data (RM 8.3 to RM 15)

Maximum Subsequent Erosion in 2008 to 2010 Erosional Areas	Area (acres)	% of Erosional Areas
Depositional/No Change (less than 6 inches)	20.1	76%
Erosional, 6 to 12 inches	5.2	20%
Erosional, greater than 12 inches	1.1	4%
Total	**26.4**	**100%**



LEGEND:

- Bridge
- River Miles

2004 Bathymetry (feet in NGVD)

- High: 11.3
- Middle: -11.1
- Low: -34.4

2008 to 2010 Erosional Areas

- 6 to 12 inches
- >= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

- 6 to 12 inches
- >= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 440 Feet

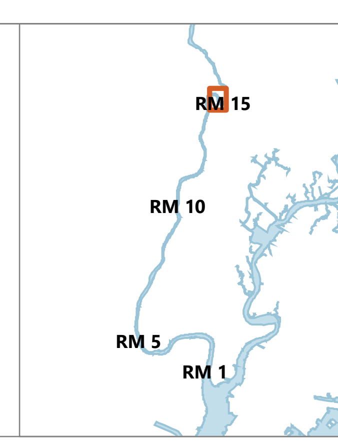


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Figure 1a

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

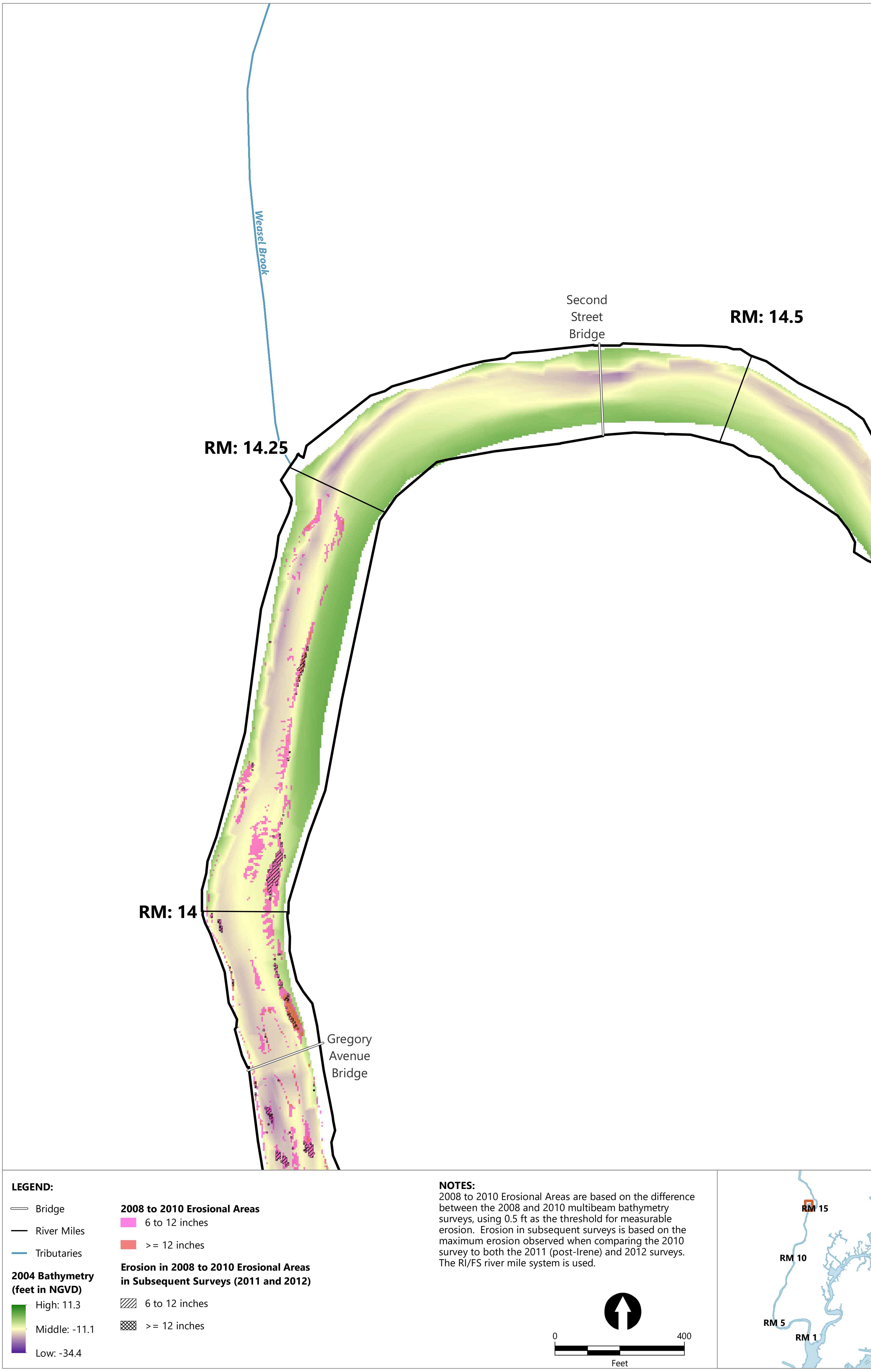

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Figure 1b
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data
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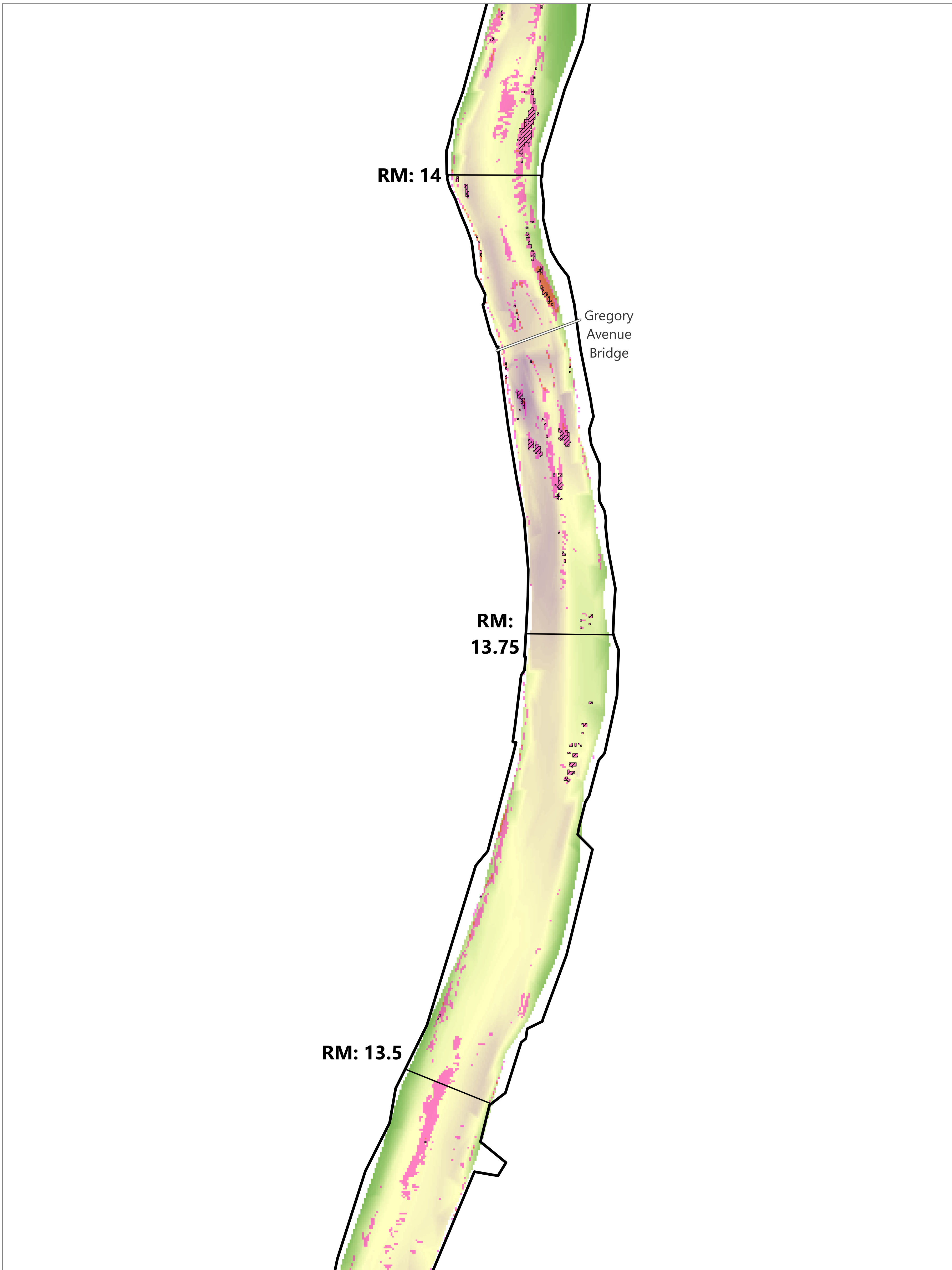

LEGEND:

Bridge

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

> = 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

> = 12 inches

NOTES:
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0 400
Feet

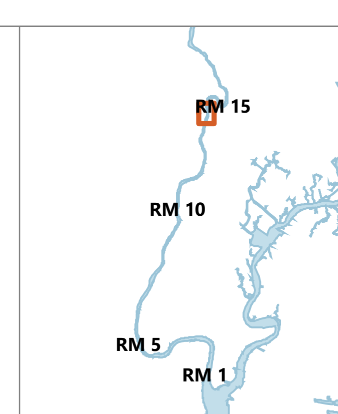

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Figure 1c

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

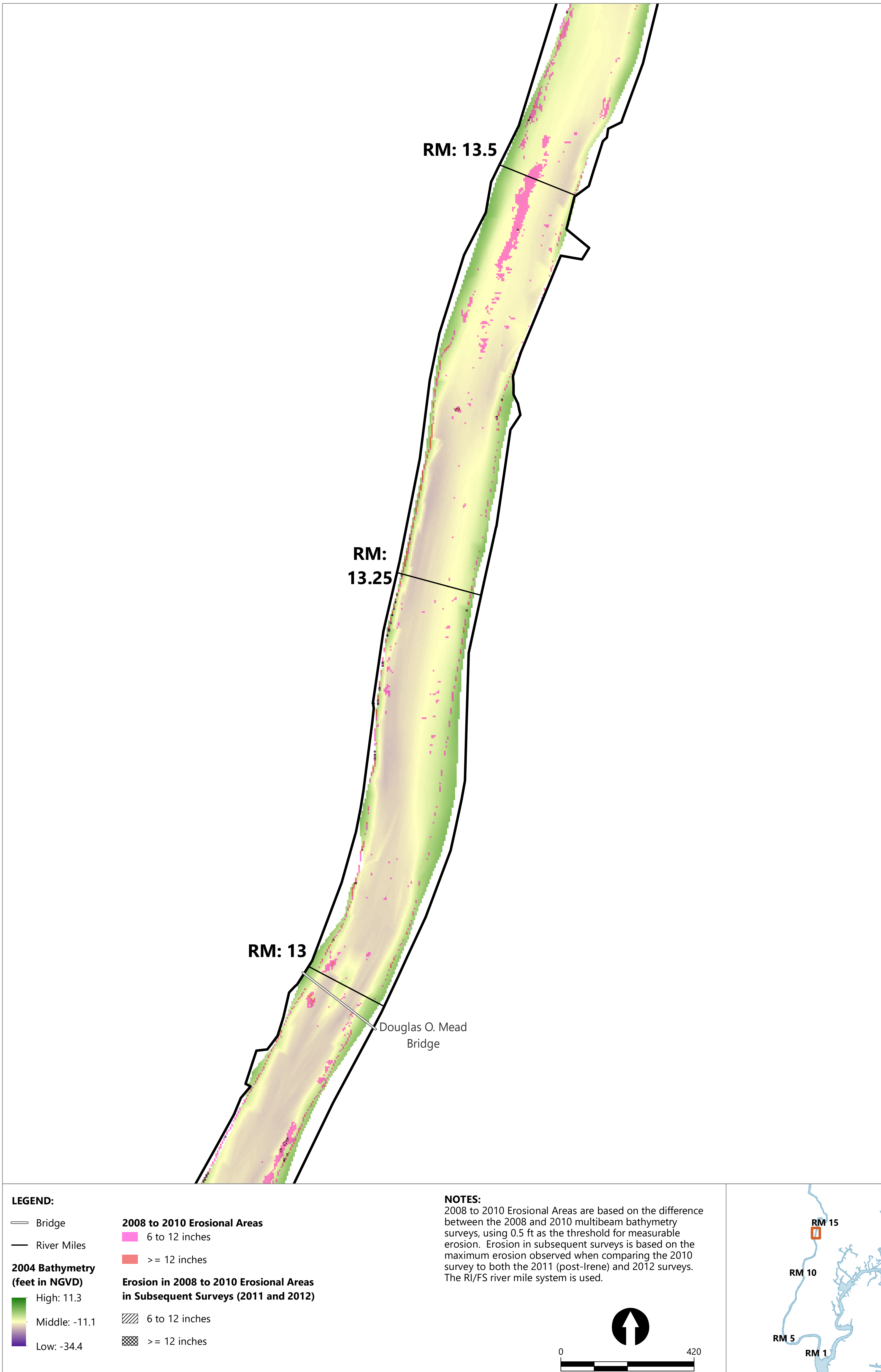

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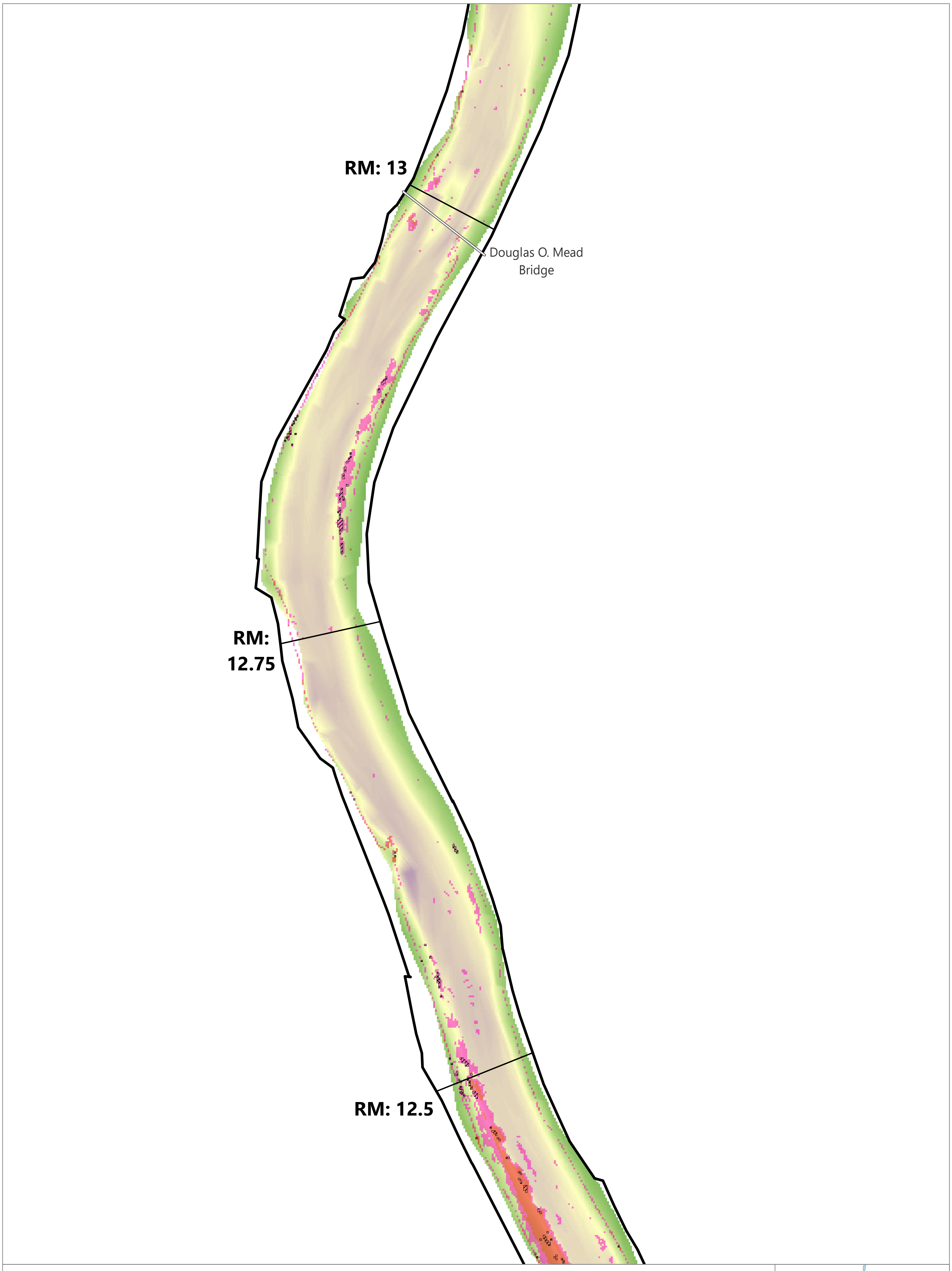
Figure 1d

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

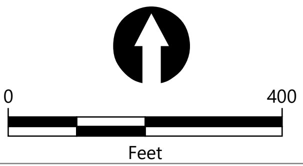
Bridge
River Miles

2004 Bathymetry (feet in NGVD)
High: 11.3
Middle: -11.1
Low: -34.4

2008 to 2010 Erosional Areas
6 to 12 inches
> = 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)
6 to 12 inches
> = 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.



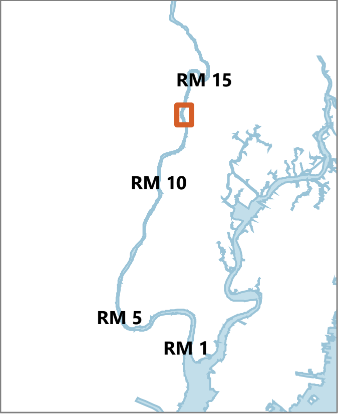


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Figure 1e
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data
Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

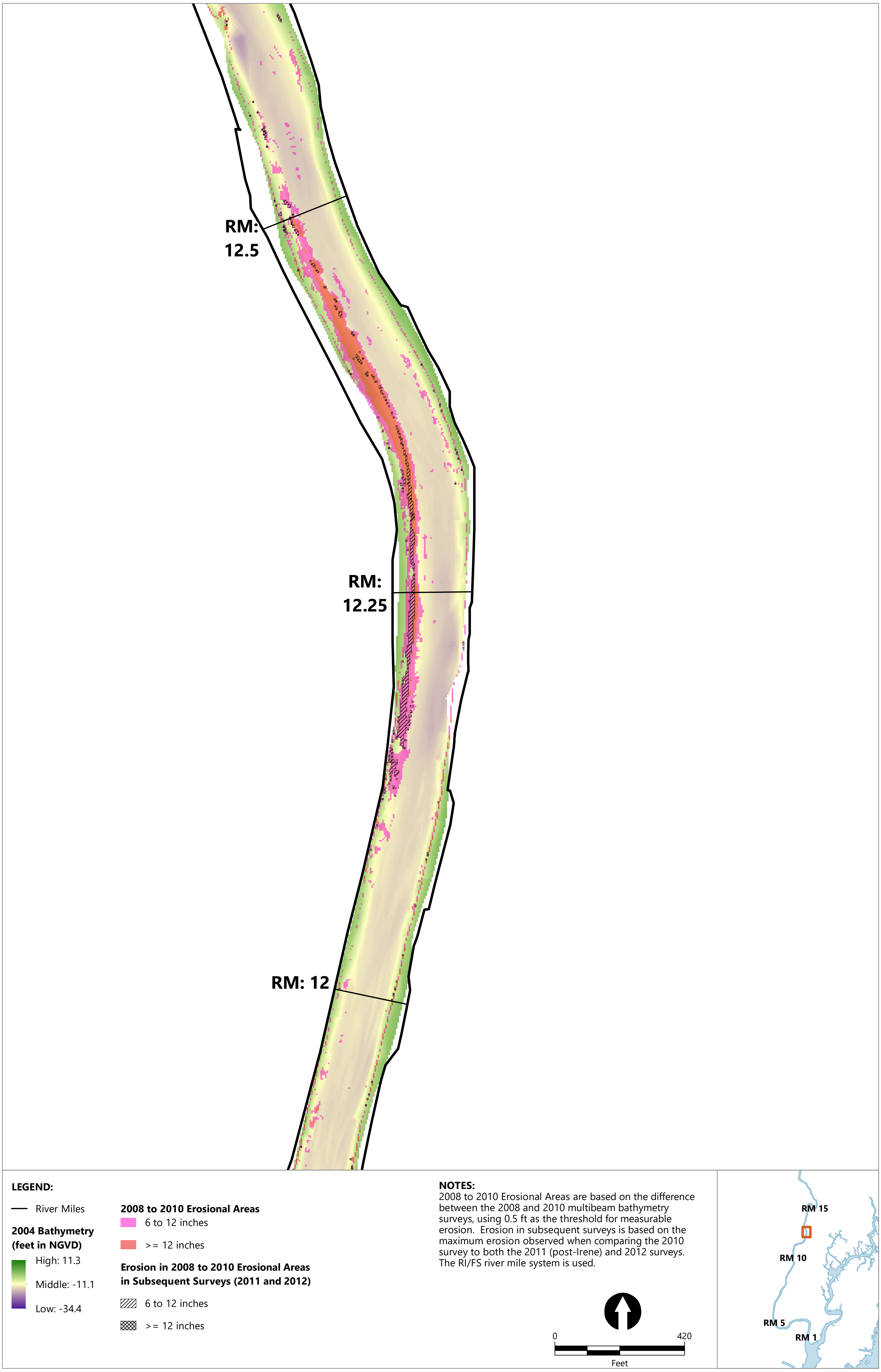

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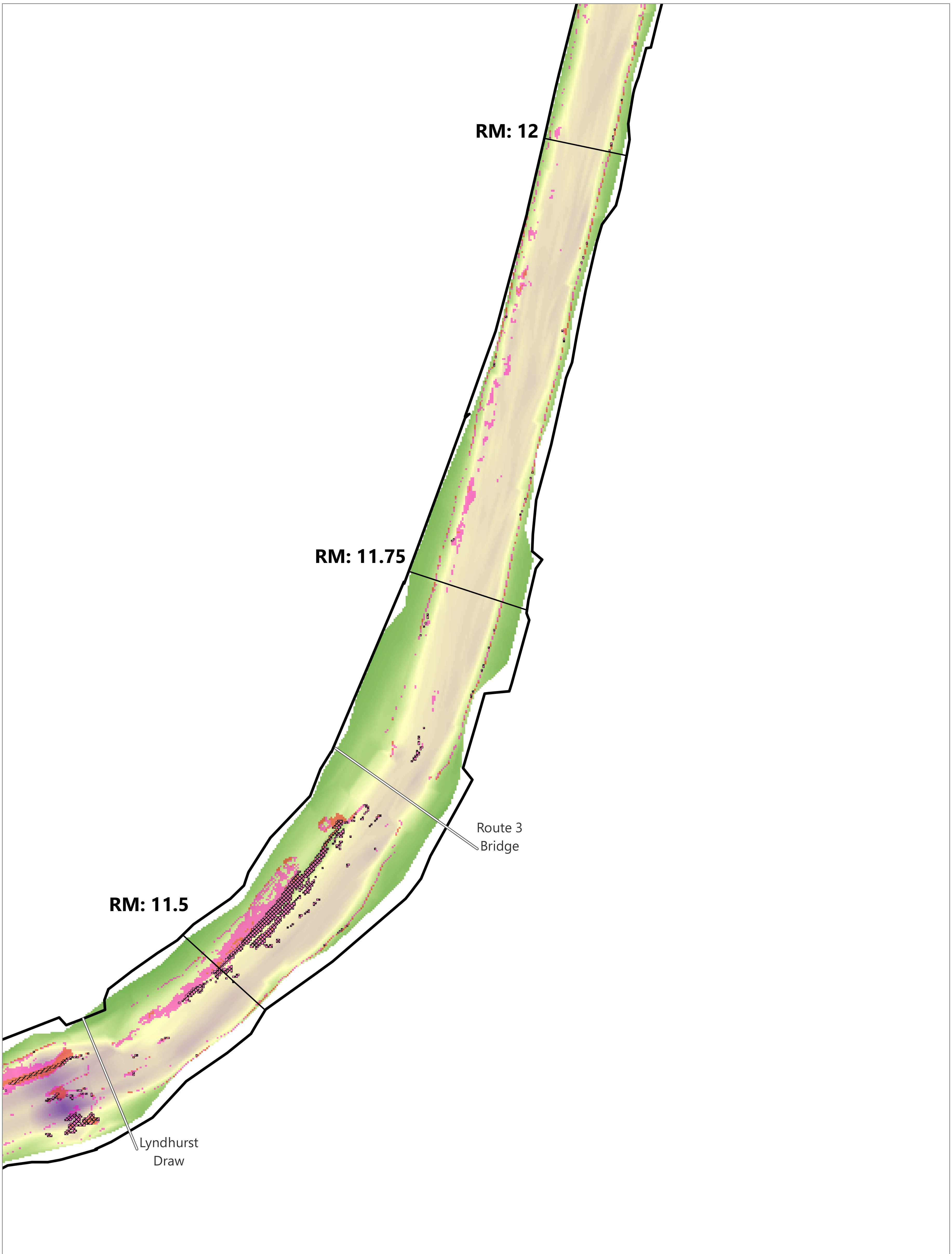
Figure 1f
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data
Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

Bridge

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
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0 400

Feet

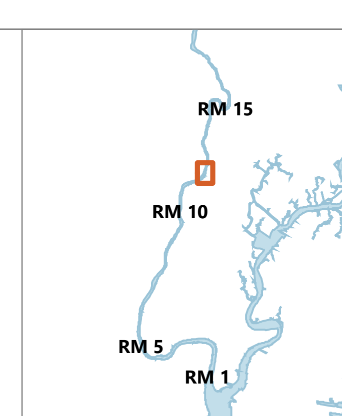

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Figure 1g

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

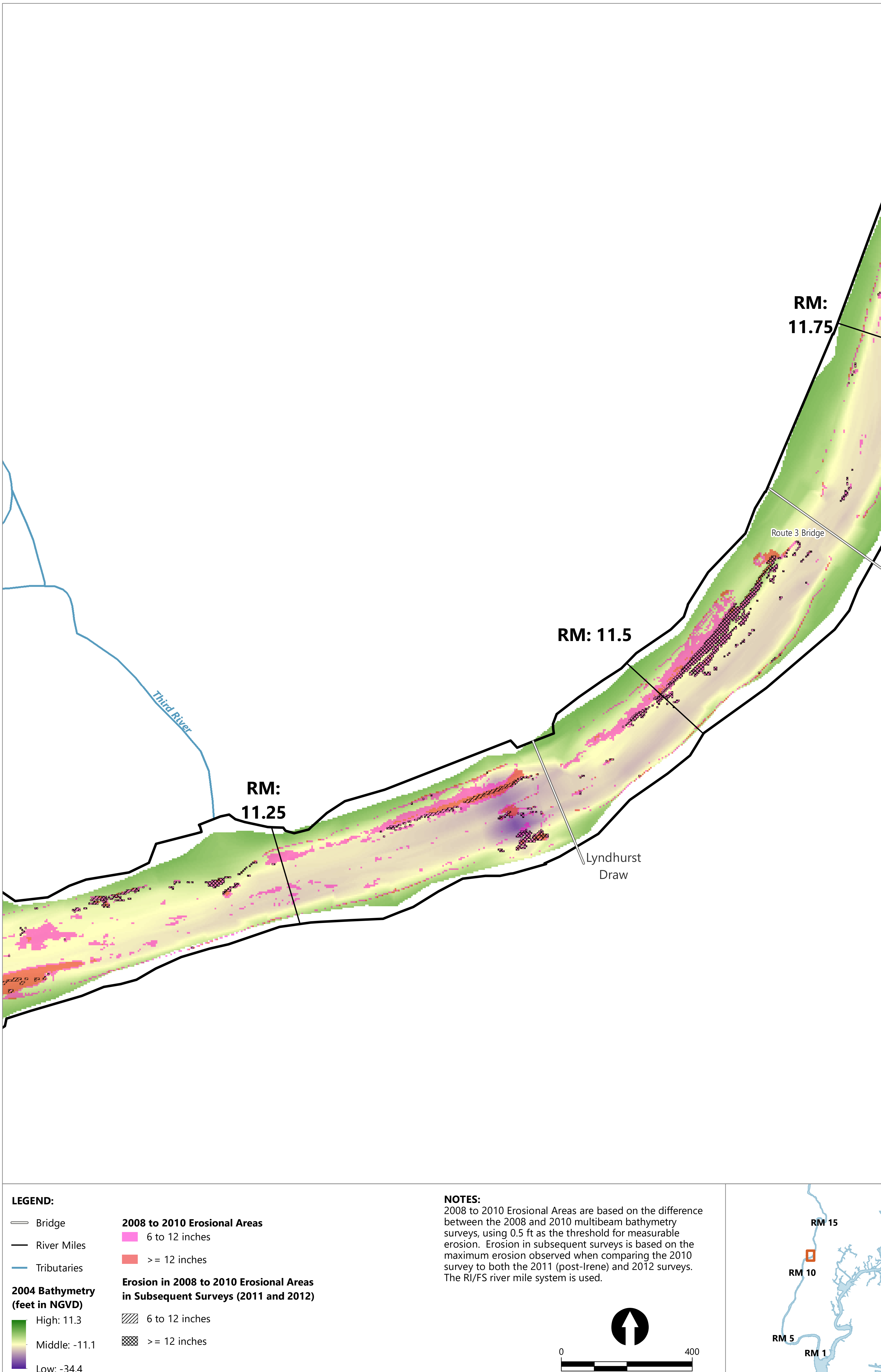

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Figure 1h
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data
Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

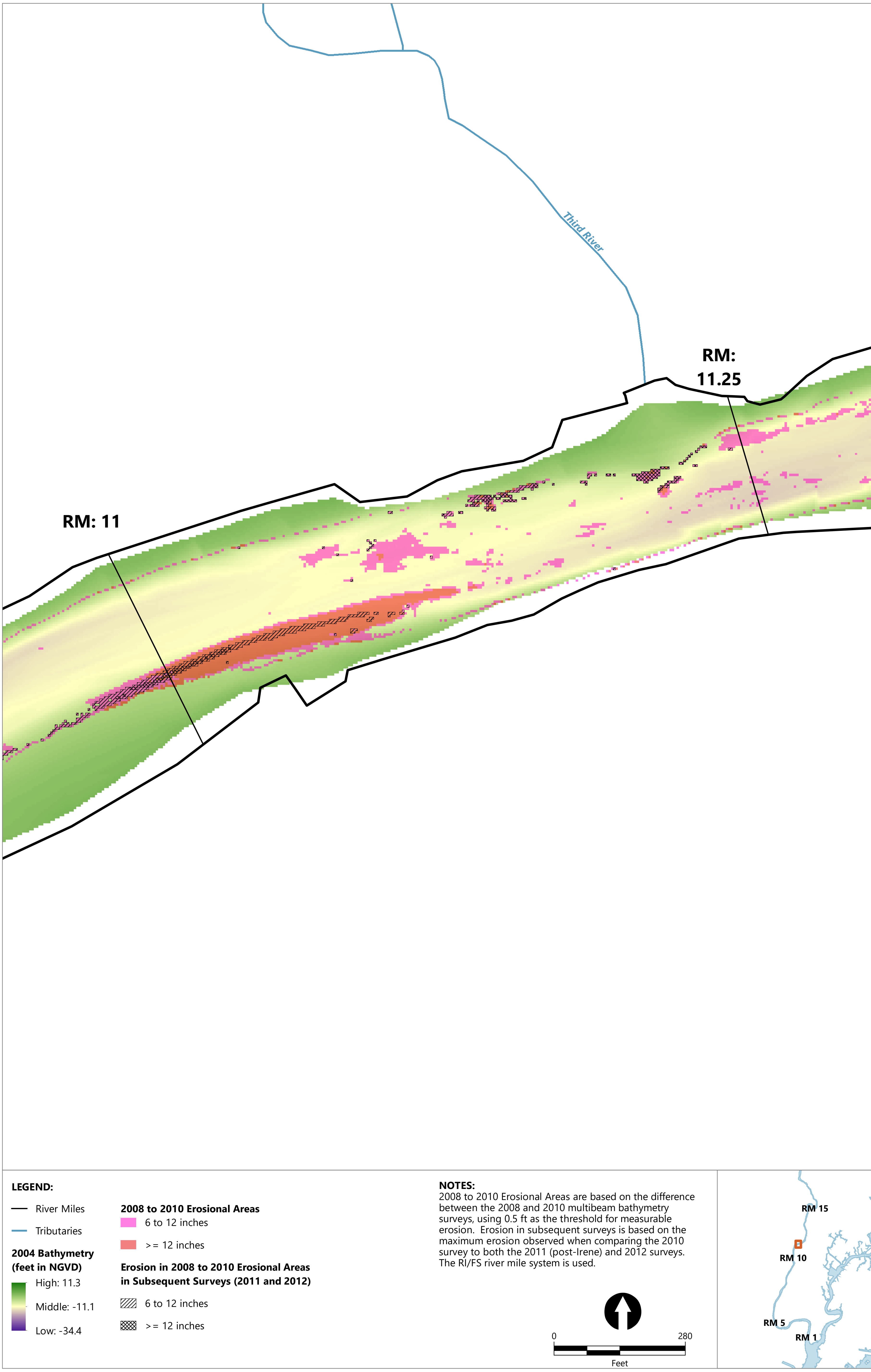

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Figure 1i
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data
Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

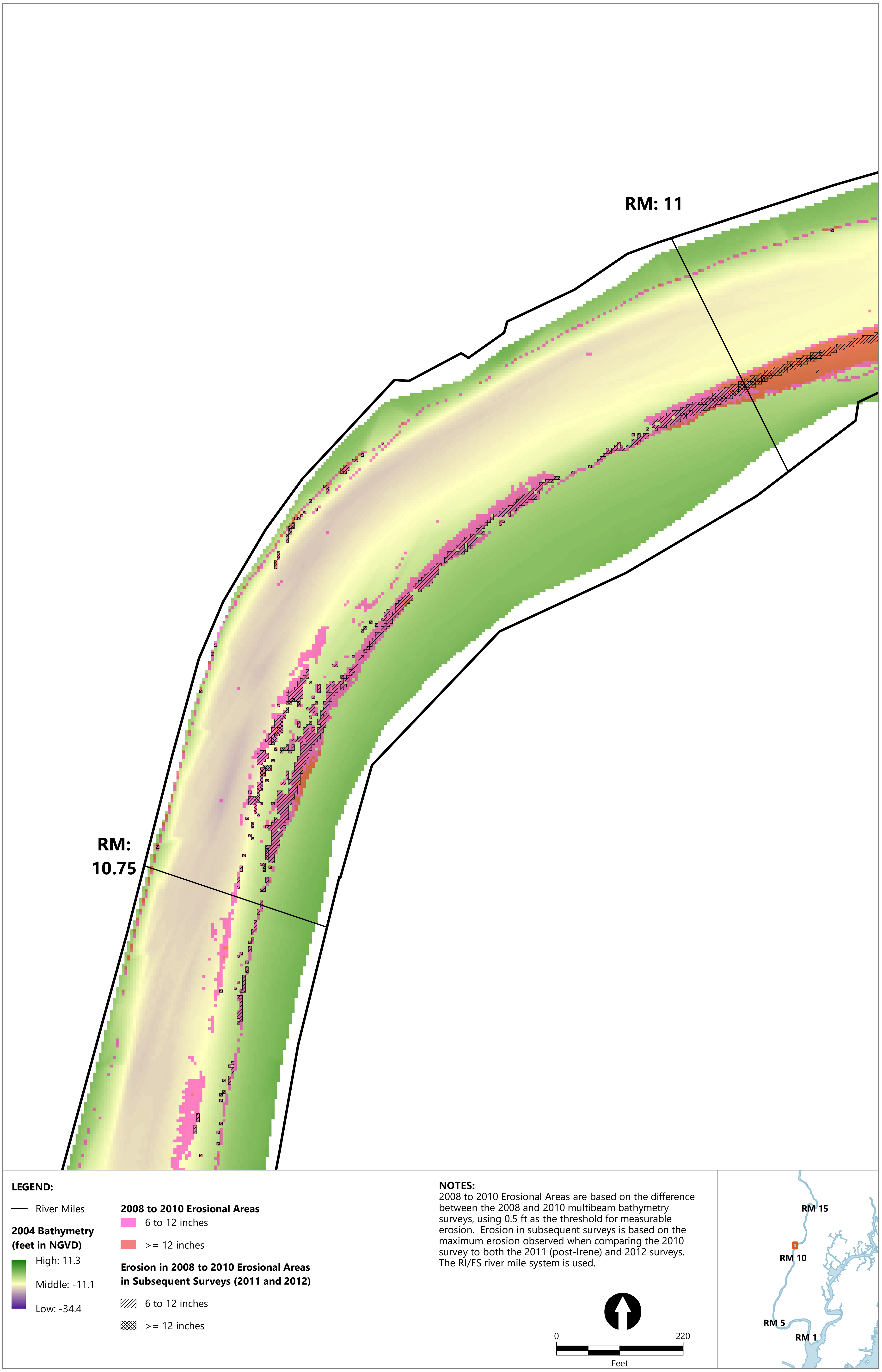

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Figure 1j
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data
Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

LEGEND:

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 200
Feet

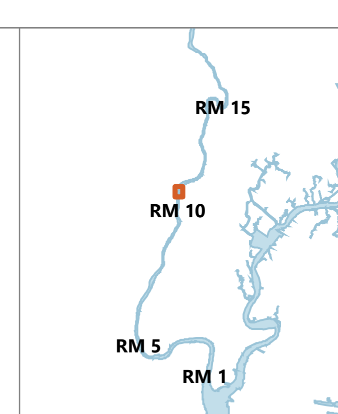

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Figure 1k
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data
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Lower Passaic River Study Area Remedial Investigation/Feasibility Study

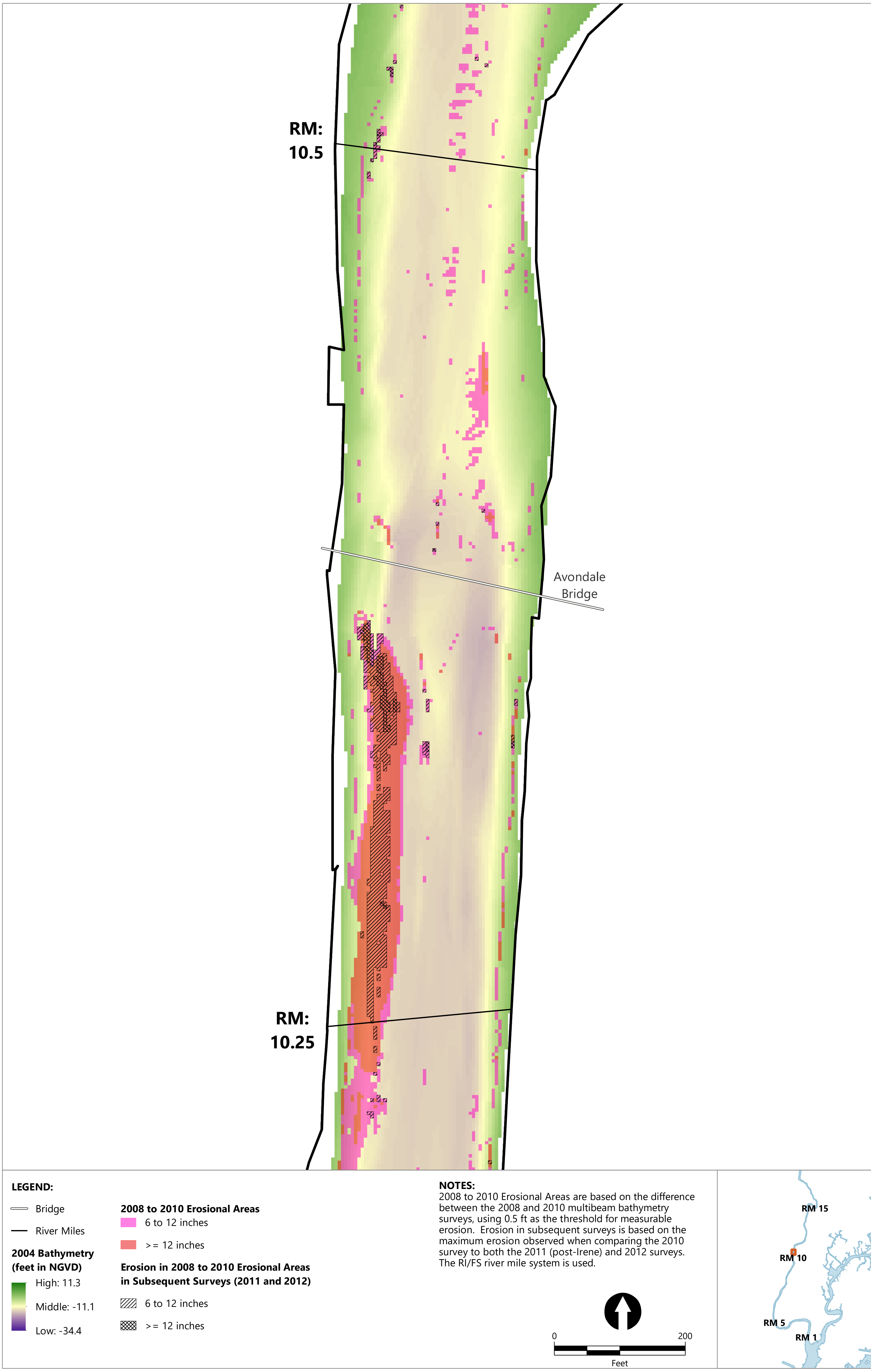

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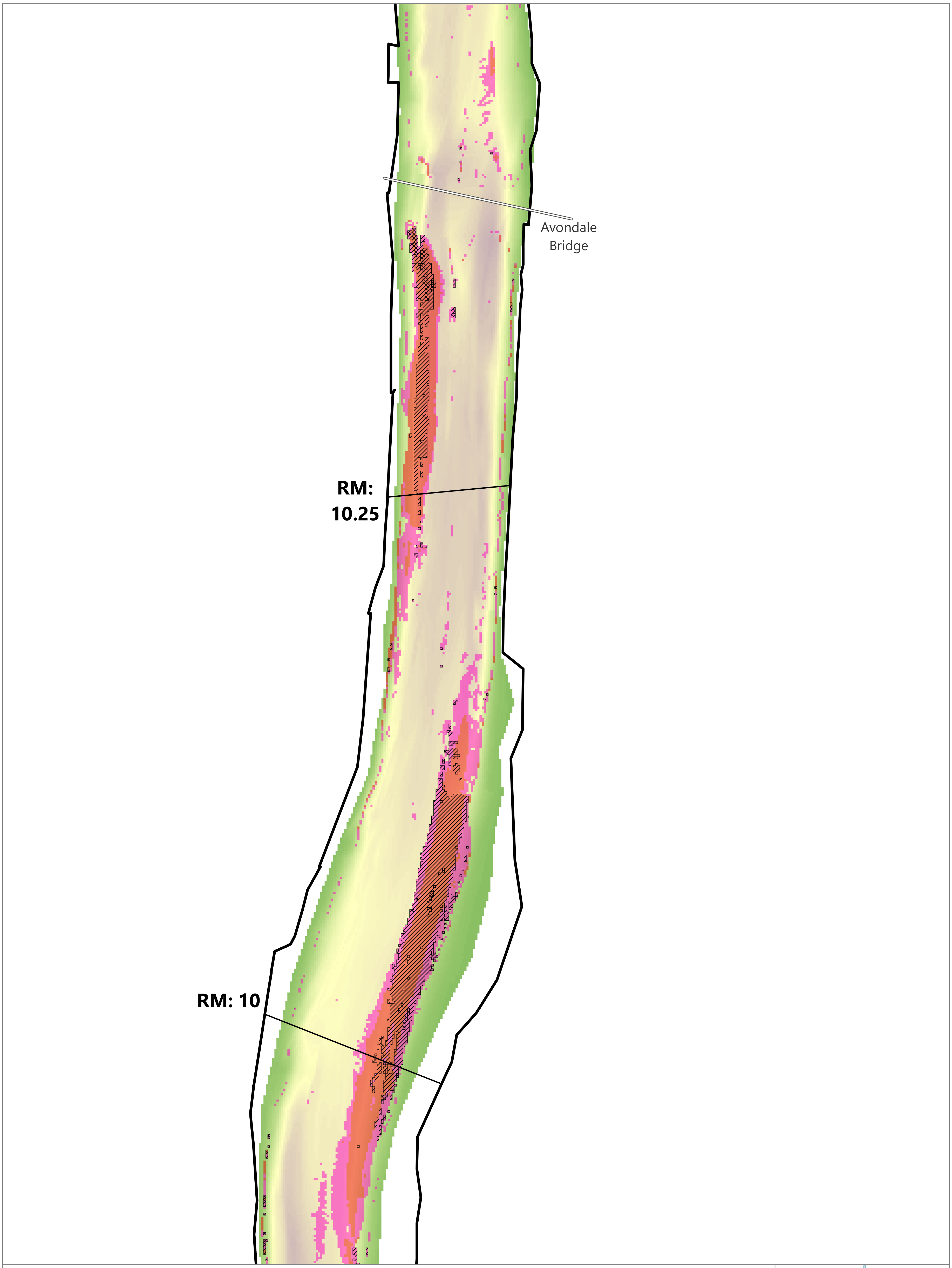
Figure 1l

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data



LEGEND:

Bridge

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 320

Feet

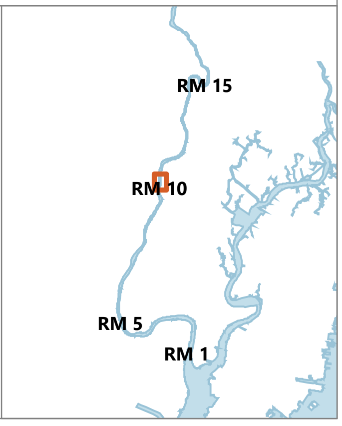


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Figure 1m

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

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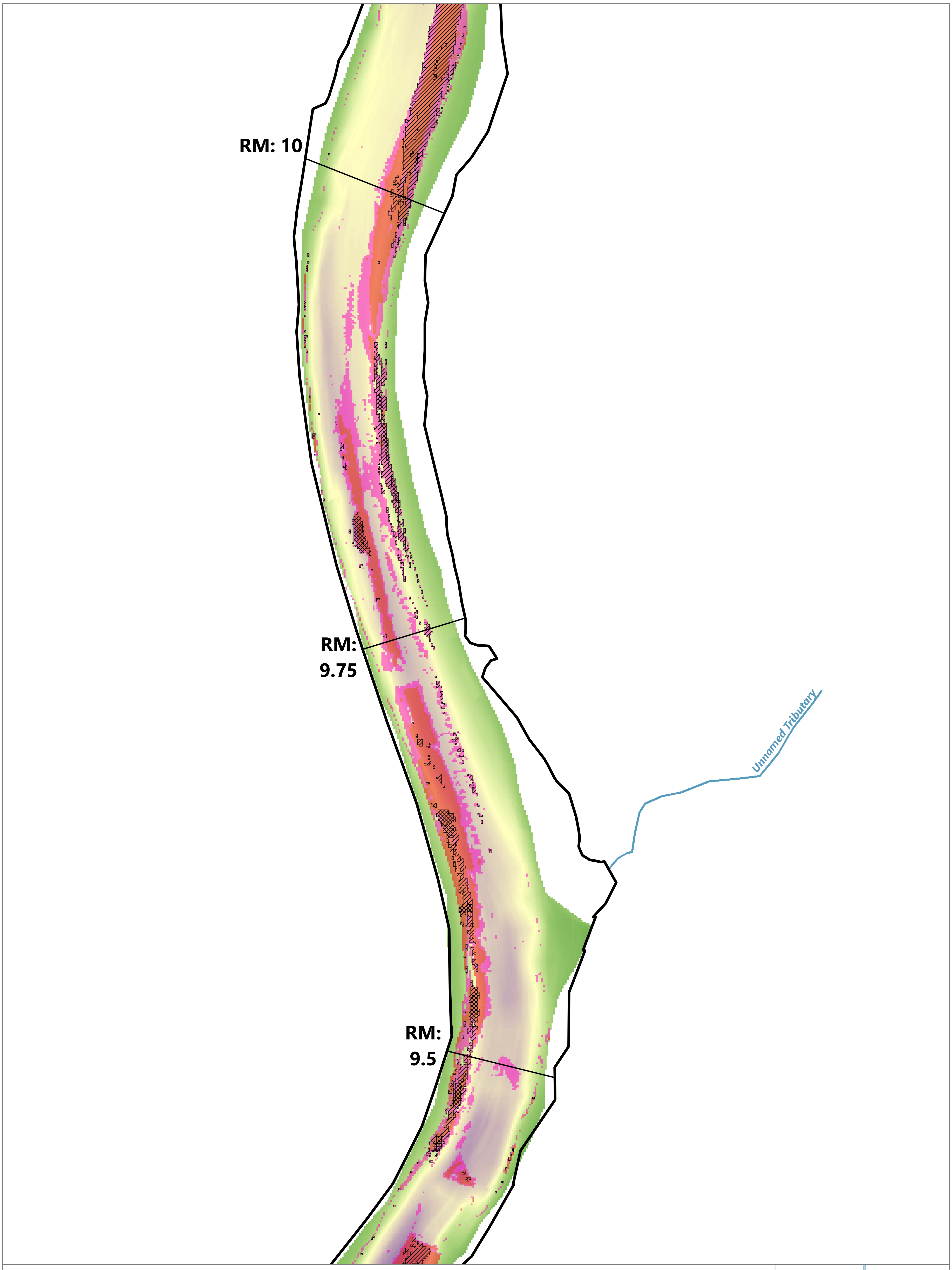
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

River Miles

Tributaries

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

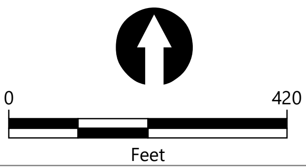
>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.



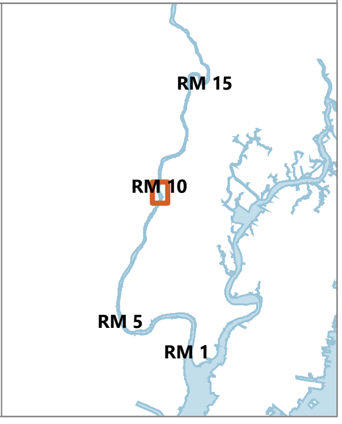


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Figure 1n

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

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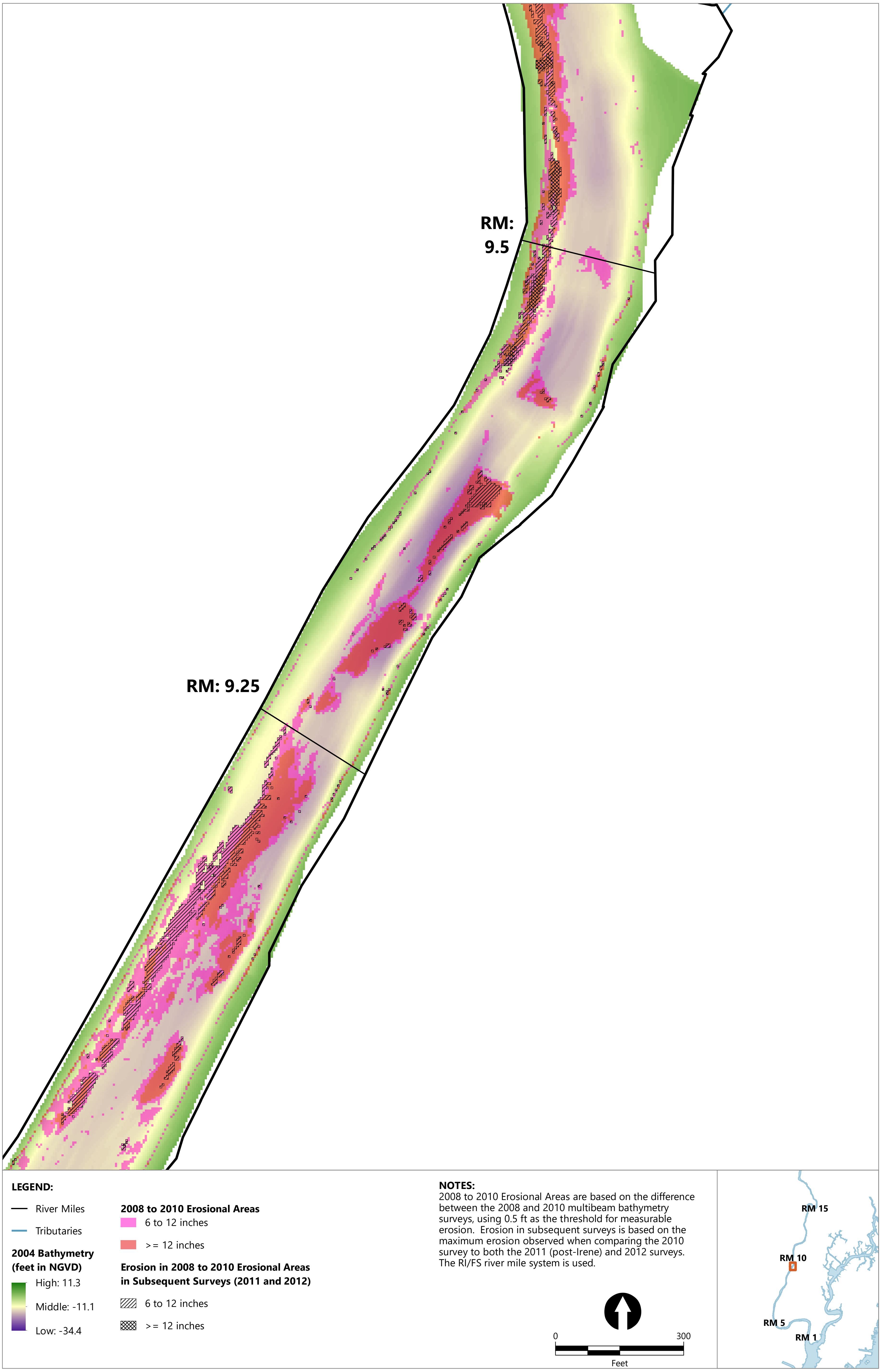

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Figure 1o

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

LEGEND:

— River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
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0 400
Feet

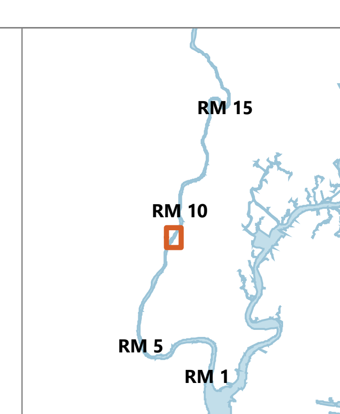

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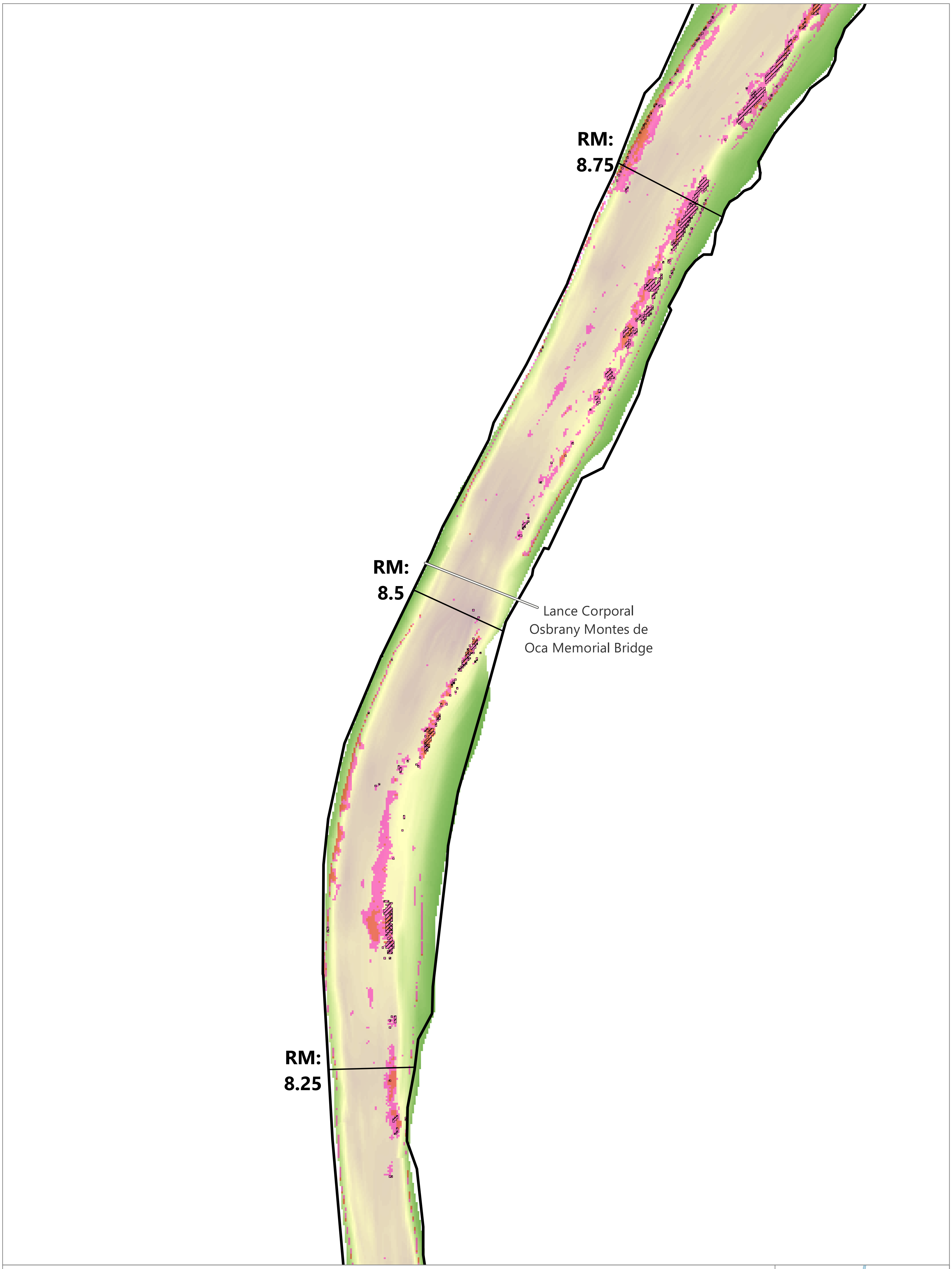
Figure 1p
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data



LEGEND:

Bridge

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

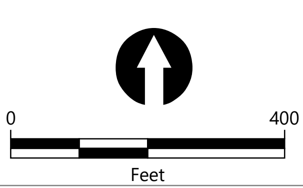
> = 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

> = 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.



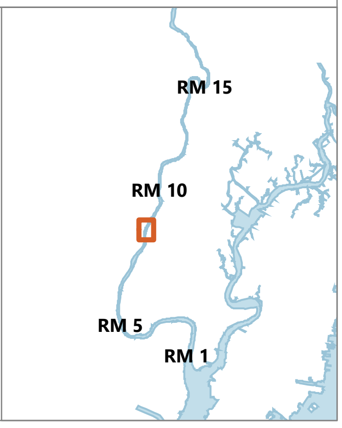


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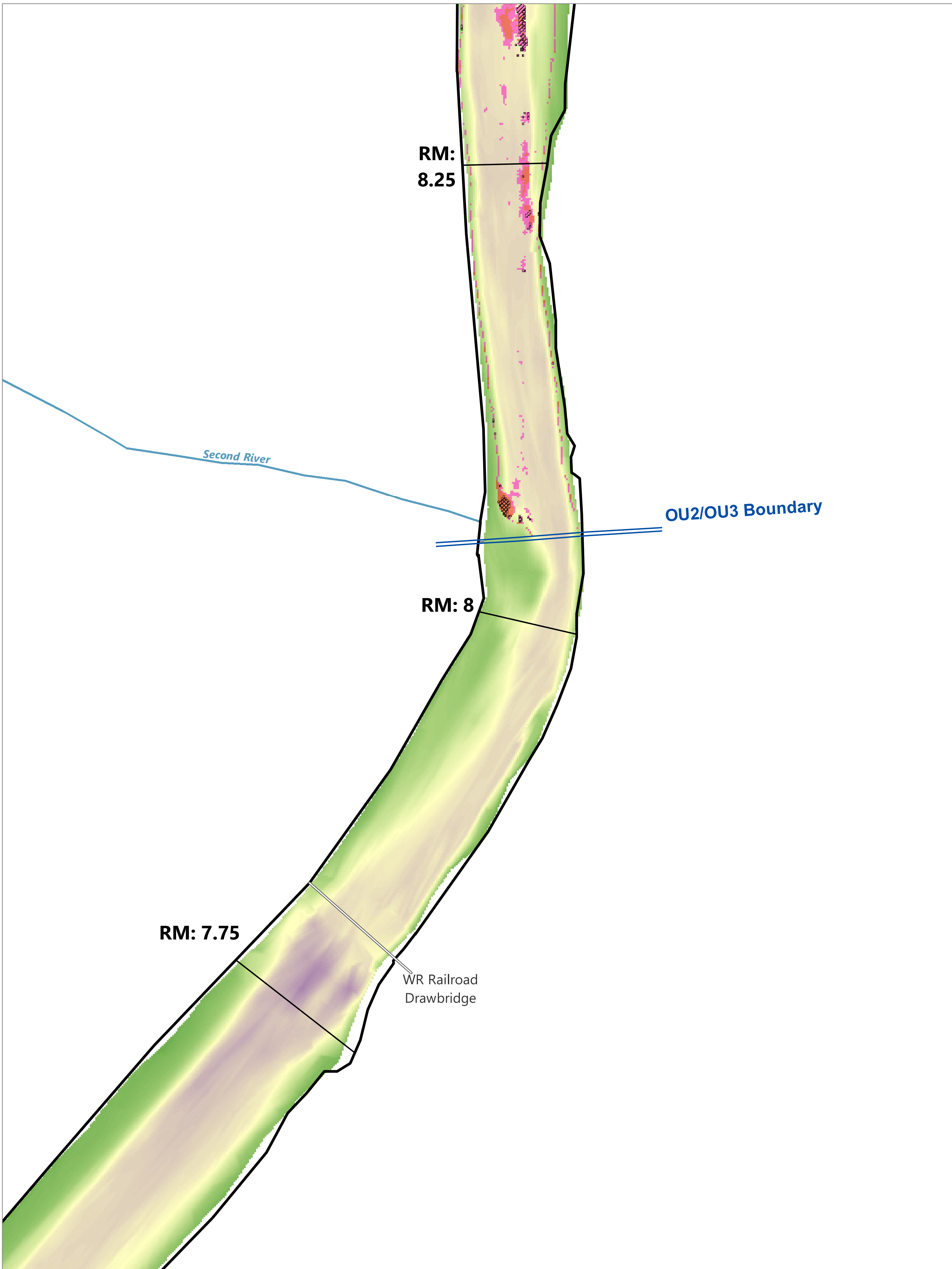
Figure 1q
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data
Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

Bridge

River Miles

Tributaries

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 420
Feet

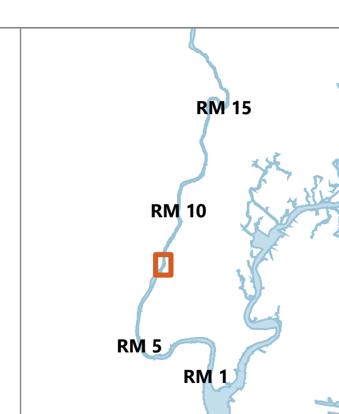


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Figure 1r

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study